

CANAIGRE INVESTIGATIONS

XII. DRYING CANAIGRE ROOTS IN A DIRECT-FIRED ROTARY DRIER

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ABSTRACT

Canaigre roots can be dried to a stable form in a rotary-type, direct-fired alfalfa drier. Root shreds dried to 12% moisture at an inlet air temperature of 900°F. showed no visible scorching or loss of tannin. The extractability of the tannin from the dried roots was substantially the same as from sun-dried shreds.

ABSTRACTO

Las raíces de canaigre pueden ser secadas a una forma estable en un secador de alfalfa rotativo y de fuego directo. Fragmentos de raíces secados a 12% de humedad por medio de una entrada de aire a una temperatura de 900 grados F. no mostraron chamusco ni pérdida de tanino. La extracción del tanino de las raíces secas era substancialmente la misma como de fragmentos secados al sol.



INTRODUCTION

Production of tanning extracts from canaigre roots (*Rumex hymenosepalus* Torr.) has been under study at this Laboratory in recent years (4). The canaigre roots used have been collected or grown by the Field Crops Branch of the Agricultural Research Service, USDA, at Mesa, Arizona. The roots must be harvested during the hot months while they are dormant. For storage throughout the year these roots have generally been shredded and sun-dried on concrete strips at the time of harvest. Most of our work was carried out on roots dried in this manner (5).

The sun-drying procedure was convenient for relatively small-scale test work, but is not too desirable for a production process. It requires large, hard-surfaced areas which will not shed pebbles or chips into the shredded roots. Even the concrete strips used for our tests were not ideal; quite a number of chips and stones from the concrete had to be removed before

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the dried shreds could be cut. This sun-drying procedure must be rapid to prevent loss of tannin by fermentation and root spoilage. It is, therefore, necessary to spread the shredded roots thinly in hot weather for the best results. Rain storms have damaged the roots and on one occasion a dust storm contaminated the shreds with excessive sand. For these reasons a more controllable mechanical drying process appears essential if dry storage is to be used.

Tray-drying or continuous-belt-drying at air temperatures below 150°F. has been satisfactorily used, but these drying methods are relatively expensive. Hence drying tests were carried out in a small commercial-size multi-pass rotary drier of the type commonly used for alfalfa.

EQUIPMENT

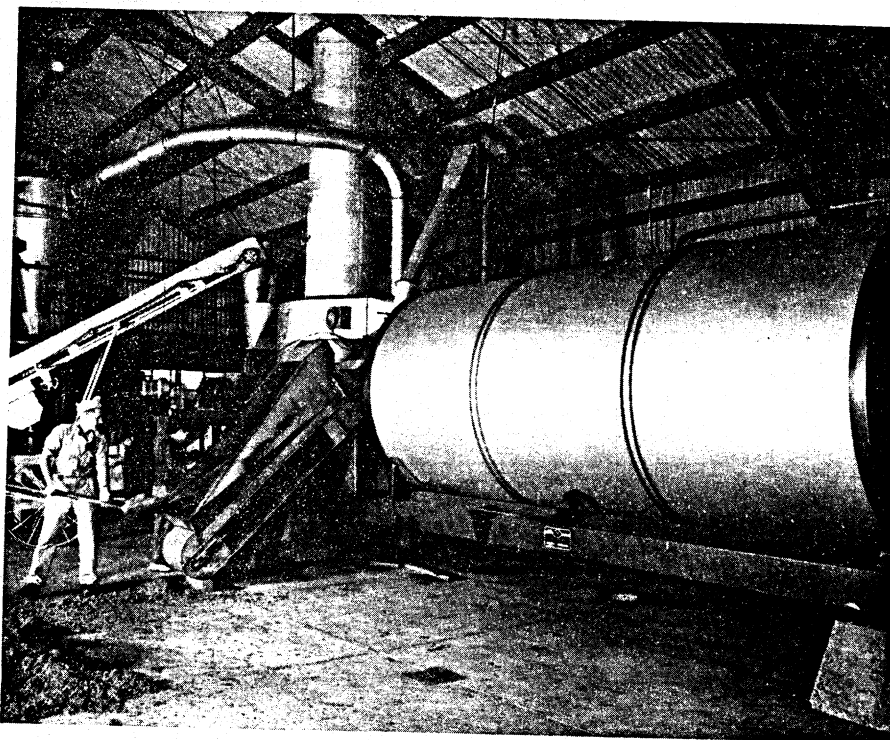
Washer.—A potato washer was used to clean the roots before shredding. It consists of a U-shaped trough divided into sections and equipped with rotating paddles that lift the roots from one compartment to the next while water flows continuously through the washer. Dirt and stones settle to the bottom of the trough and are flushed out periodically.

Cutter or Shredder.—The roots were cut either in a Fitzpatrick Model D comminuting machine* with sharp knives to pass through a screen with 1/2-inch diameter openings, or in a shredder equipped with three beet knives (H. Disston & Sons, Philadelphia, Pa., No. 9-40-A). The shredder was built at this Laboratory from a description by Kummer (2).

Drier.—The drier used was the Heil rotary dehydrator, Model PD 7-16, shown in Figures 1 and 2. This is a small commercial-size, double-pass, direct oil-fired, steel rotary drier commonly used for alfalfa. The rotating body, which is 16 feet long, is made up of three concentric cylinders, 2 1/2, 5, and 7 feet in diameter, respectively. The inner cylinder is the combustion chamber. The oil burner is mounted at one end of this cylinder and protrudes from the main body, as shown at the right side of Figure 2. The drying air, drawn in by an exhaust fan through openings adjacent to the burner, is heated by mixing with the products of combustion.

The material to be dried is fed on to the elevator, from which a screw feeder forces it into the left end of the drier. Here it meets the heated air and products of combustion and is carried by them, in the annular space between the inner cylinder and the 5-foot cylinder, to the right end of the body, then back between the 5-foot cylinder and the outer one to the left end. Here the gases and the dried material enter the exhaust fan, which delivers them to the cyclone separator adjacent to the drier. The hot gases escape through the top of the separator, and the dried material falls through the bottom. Here a

*The mention of commercial products and companies anywhere in the paper does not imply that they are endorsed or recommended by the Department of Agriculture over others of a similar nature not mentioned.



Courtesy of U.S.D.A. Photo by M. C. Audsley

FIGURE 1.—Double-pass, direct oil-fired rotary drier.

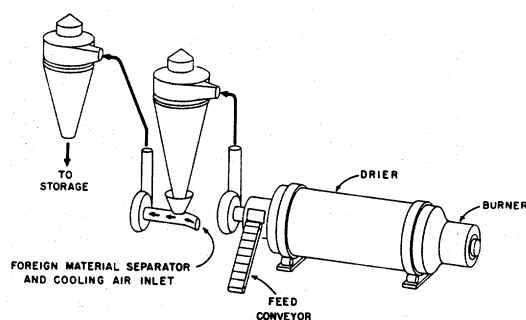


FIGURE 2.—Drier diagram.

stream of cold air entering a second fan picks up the dried material and sends it to a cooling cyclone separator. The velocity of this air is insufficient to pick up stones or gravel; any such material that has entered the drier falls out through a tee in the duct at this point. The dried material falls into bags at the bottom of the second cyclone.

TABLE I
DRYING CANAIGRE ROOTS* IN DIRECT OIL-FIRED ROTARY ALFALFA - TYPE DRIER

	SERIES I					SERIES II							
	Run 6	Run 4	Run 2	Run 5	Run 1	Run 10	Run 9	Run 7	Run 12	Run 11	Run 8	Run 13	
Root cutter**	F	F	F	F	K	K	K	K	K	K	K	K	
Cutter speed, r.p.m.	2300	2300	3180	2300	850	850	850	850	850	850	850	850	
Inlet air temp., °F.	630	844	1005	1215	810	628	816	871	951	1045	1099	1240	
Exit air temp., °F.	237	242	228	247	241	287	284	277	284	293	285	283	
Feed rate, lb/hr	1156	2295	3200	4545	1896	908	1396	2079	1920	2400	2810	3360	
Feed root moisture, %	63.3	61.0	60.1	62.2	61.2	71.3	69.8	71.0	70.3	69.2	70.5	73.0	
Av. drying time, min.	—	—	—	—	—	12.1	10.4	13.0	12.0	12.5	7.2	15.3	
Flue gas rate, cu. ft/hr (x1000)***	—	—	—	—	—	220	210	195	—	195	220	—	
Product rate, lb/hr	511	1011	1440	1990	849	292	467	708	634	831	931	1024	
Product moisture, %	17.1	11.4	11.3	13.7	13.2	11.9	11.4	13.8	10.0	11.1	11.5	12.9	
Water evaporation, lb / hr	645	1284	1760	2555	1047	616	929	1371	1286	1589	1879	2336	
Oil consumption, gal/hr	9	16	21.5	28.5	15	11.3	14.7	16.8	17.1	19.1	22.6	25.9	
Water evaporation, lb/gal of oil	72	80	82	90	70	54.5	63.2	81.6	75.2	82.1	83.1	90.2	
Thermal efficiency, %†	56.8	63.1	64.4	70.5	54.9	42.6	49.4	63.8	58.8	64.3	65.0	70.5	
Drier capacity, lb. water evaporated/ hr/cu ft. ††	1.20	2.39	3.28	4.75	1.95	1.15	1.73	2.55	2.39	2.92	3.50	4.35	
Tannin†, %, m.f.b., feed roots	††	††	††	††	††	28.8	29.4	29.0	28.8	28.1	29.5	30.1	
" " " dried roots	30.7	31.5	31.2	29.3	31.7	28.9	28.9	29.3	27.4	26.9	25.8	23.4	
Purity‡, % (soluble solids) feed roots	††	††	††	††	††	49.1	48.9	50.0	50.4	48.3	49.7	51.3	
" " " dried roots	59.1	59.8	60.4	58.5	60.7	49.6	48.9	49.3	49.9	48.5	48.1	47.6	
Iron, p.p.m., feed roots	150	140	—	140	119	—	—	—	—	—	—	—	
" " " dried roots	240	300	—	120	283	—	—	—	—	—	—	—	

*Willcox strain roots grown 2 years from seed; Series I and II tests on roots harvested in successive years.
 **F=Fitzpatrick comminuting machine; all roots cut with sharp knives to pass through $\frac{1}{8}$ " perforated screen.
 K=Kummer shredder with 9-40-A beet knives.
 ***Standard conditions; dry, 60°F., 1 atmosphere.
 †% of oil-heating value used to heat roots and evaporate water.
 ††Drying zone 537 cu. ft.
 ‡Determined by extraction with 50% acetone, evaporation of acetone (3), ALCA method (1) on residue.
 †††Representative roots from Series I lot tray-dried at 125°F. contained 32.2% tannin, of 60.5% purity (soluble solids).
 This closely represents the feed analysis of all runs in Series I.

EXPERIMENTAL RESULTS

Two series of drying tests were made using two-year-old cultivated Willcox strain roots harvested in successive years. The drying data are summarized in Table I. Substantially identical roots were used in runs of a single series, except for run No. 13 where the roots used were from a slightly different blend. Since the strain of roots degenerated with successive seedings, the Series II roots had lower tannins and purities than those of Series I.

The Fitzpatrick cutter, which was used for all the Series I roots except one, produced chips considerably finer than $\frac{1}{2}$ inch although a $\frac{1}{2}$ -inch screen was used. The Kummer shreds (run No. 1 of Series I and all of Series II) were as long as 1 to 2 inches with many smaller particles. They were materially coarser, on the average, than the roots cut by the Fitzpatrick machine.

A product moisture of about 12% was sought and, except for run No. 6, was obtained within reasonable limits for all runs. This was achieved by first controlling the inlet air temperature through adjustment of the fuel rate (since the fan speed was fixed), and then varying the rate of feeding the roots until the desired product moisture was approximately reached, as indicated by a Steinlite moisture tester.

For the Series II runs the average drying time of the roots in the drier was about 12 minutes. This was calculated from the dry weight of material left in the drier at the end of the run and the root solids feed rate. Flue gas rates were calculated for some runs from the oil feed rate and an Orsat carbon dioxide analysis of the flue gases. They averaged about 200,000 cu. ft. per hour (dry, 60°F., 1 atmosphere) with no apparent significant trend. These values are only rough approximations, however, since they were calculated from very low carbon dioxide values.

In both series of tests there was an increase in the tannin loss during drying as the inlet air temperature was increased, as shown in Table I and Figure 3. This increased loss was accompanied by visible scorching and darkening of the product roughly in proportion to the loss of tannin. The smaller particles, which dry first, were most scorched. When drying to 11 or 12% moisture, this damage became perceptible at inlet air temperatures above 900°F. Below this temperature the loss would be about 2% or less of the tannin fed.

Canaigre roots must be dried below about 18% moisture to prevent mold growth and loss of tannin during storage, but they should not be dried to a lower moisture content than is necessary. With excessive drying in this machine, which was observed during the early parts of some runs before equilibrium was reached, the product temperature rose above 212°F., causing visible scorching and substantial loss of tannin. One sample, dried to 6.3% moisture, lost 62% of its tannin, while another, dried to 8.0% moisture, lost 33% of its tannin. Drying to 11 or 12% moisture, as was done in the tests reported, kept tannin destruction to a minimum because the average product temperature did not rise above about 212°F.

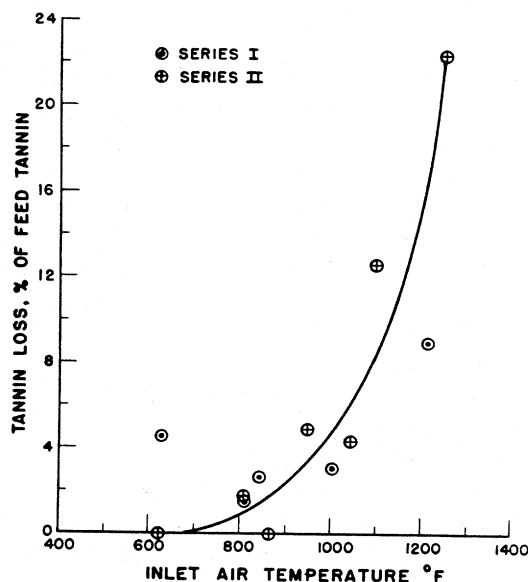


FIGURE 3.—Variation of tannin loss with inlet air temperature during rotary drying of canaigre roots.

The scorching obtained with overdrying, or drying at too high an inlet air temperature, was a function of the relative particle sizes as well as the inlet air temperature and the final product moisture. Individual particles scorched only when they were dried to such an extent that evaporative cooling was no longer sufficient to keep them near the wet bulb temperature. This occurs first with the smaller particles, which become dry midway through the drier where the air temperature is still high enough to destroy tannin. Hence a uniform feed particle size would permit use of a higher inlet air temperature (and a higher root feed rate) to yield the same final product moisture without scorching, because all particles would dry at the same rate and drying could be more easily controlled.

For both series of tests the drier capacity and the thermal efficiency increased with the inlet air temperature, as shown in Figures 4 and 5. In each case the Series I curve is higher than the Series II curve because of the finer cut obtained in the Fitzpatrick cutter. The values for the one lot of Series I that was cut in the Kummer shredder (Run 1) were also below the other Series I points for the same reason.

The iron content of the roots was approximately doubled, from about 140 to about 280 p.p.m., by processing in this steel equipment as shown by the Series I data (Table I). This is not believed a serious increase, however, since color skivers did not show iron discoloration, and since the iron contents (m.f.b.) of concentrated tanning extracts produced from these rotary-dried roots were much lower than the iron contents of the dried roots (m.f.b.). Table II lists iron contents of extracts produced from the Heil-dried roots

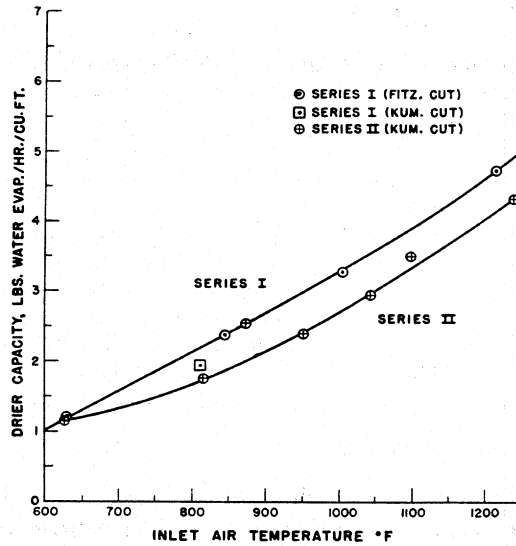


FIGURE 4.—Variation of drier evaporative capacity with inlet air temperature.

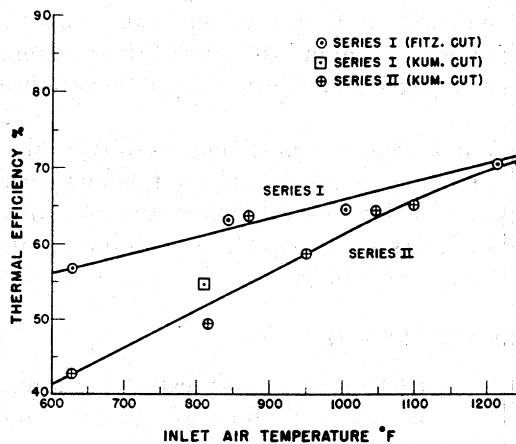


FIGURE 5.—Variation of thermal efficiency with drier air inlet temperature.

compared with the iron content of two extracts from roots not dried in contact with steel. The iron contents fluctuate too widely to show a significant difference.

Comparative extraction tests on the Series I roots dried at various temperatures in the rotary drier and on the same roots dried at 125°F. in a tray drier were made with water at 150°F. in a Kennedy-type continuous countercurrent extractor and in a single-batch mixing unit. Extractability of the tannin in the roots rotary-dried at all temperatures was about the same as that of the tannin in the roots tray-dried at low temperature which were taken as a standard. The only difference observed was that the rotary-dried roots became a little softer and more mushy during extraction.

TABLE II
IRON CONTENT OF CONCENTRATED CANAIGRE TANNING EXTRACTS

Root Drier	Root Drying Run	Extract No.	Inlet Air Temperature °F.	Iron p.p.m. m.f.b.
Tray	—	109	125	114
Tray	—	116	125	30
Rotary	6	114	630	120
Rotary	6	115	630	59
Rotary	4	112	844	28
Rotary	2	108	1004	66
Rotary	5	113	1215	110

CONCLUSIONS

Canaigre roots can be dried in a rotary, direct-fired, alfalfa-type drier without material loss of tannin where the conditions are such that little or no scorching is visible in the product. For maximum capacity and thermal efficiency the drier should be operated at the highest inlet air temperature which can be attained without excessive tannin loss. Such loss is minimized when the roots are dried only to the highest moisture content consistent with good storage.

In the Heil drier used for these studies the maximum desirable inlet air temperature is about 900°F. for roots being dried to about 12% moisture. A higher inlet air temperature could probably be used if the roots were dried to a higher moisture content or if the roots were cut to a more uniform particle size so that all particles would dry at the same rate.

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